An Information Systems Roadmap

Richard Neal
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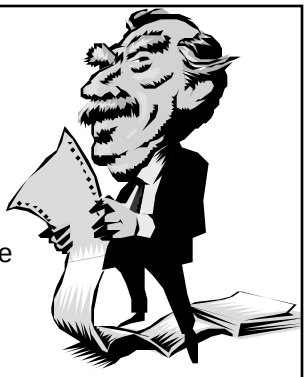
IMTI is an enabling organization dedicated to consensus, crosscutting, living plans and cooperative solutions for manufacturing success

What If . . .



We had a plan, put together by experts from multiple sectors that -

- Was built around manufacturing functions
- Defined the critical elements of manufacturing technology
- Defined a vision for each important category
- Provided a migration plan to get us from where we are to where we need to be
- Presented the information in various levels of detail
- Could be used as a guide for our specific technology needs

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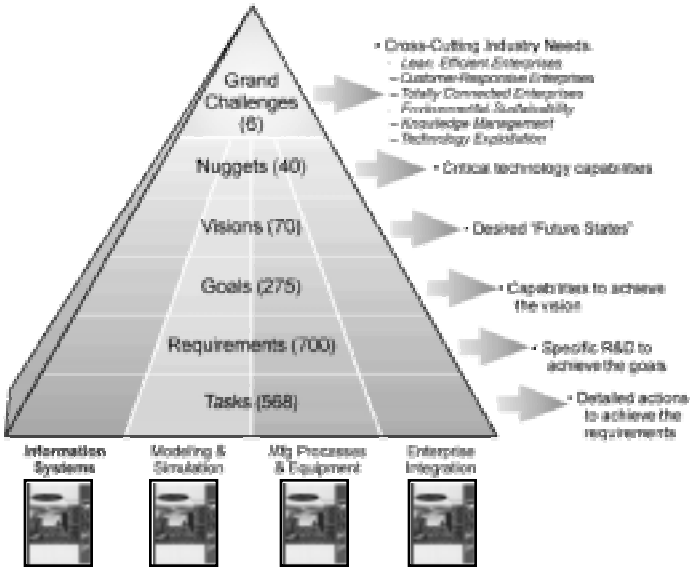
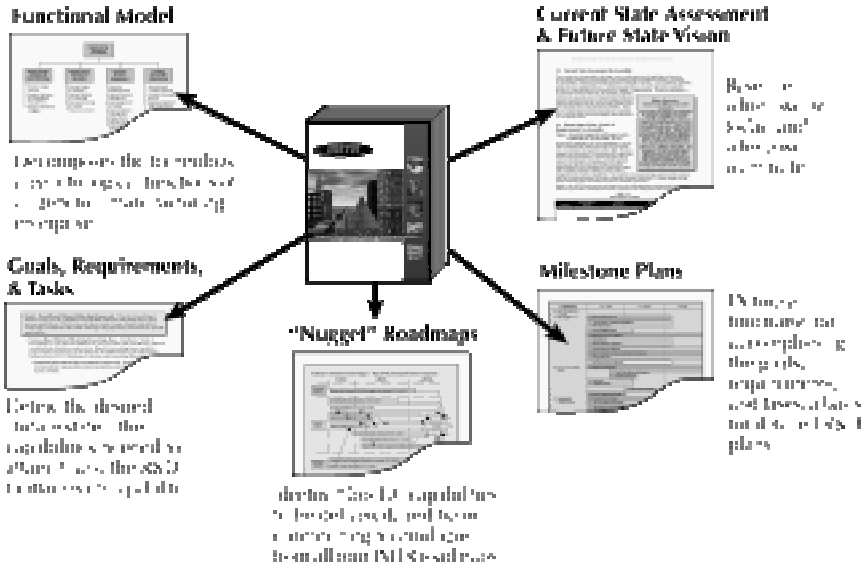
IMTI



IMTI Deliverables Format



What If . . .

. . . The IMTR roadmaps were "living documents that allowed me to:

- Select the topic of interest to me
- Go directly to the information that I need
- Find who has solutions and who is working in any area that I choose
- See where my tax dollars are being spent and how I could apply the results
- Compare my technology strategies against a group consensus

AND

What If . . .

- The documents were kept current and on-line
- The key topics were defined and prioritized
- Validated, key issues were identified as rallying points for focused activity
- More detailed roadmaps were developed that addressed the most important topics
- The detailed plans were adopted by companies, research organizations, and the government funding agencies
- "Volunteer Armies" and Focus Groups worked together to leverage investments and deliver solutions

?????????

That's the Promise of

To The Issue At Hand

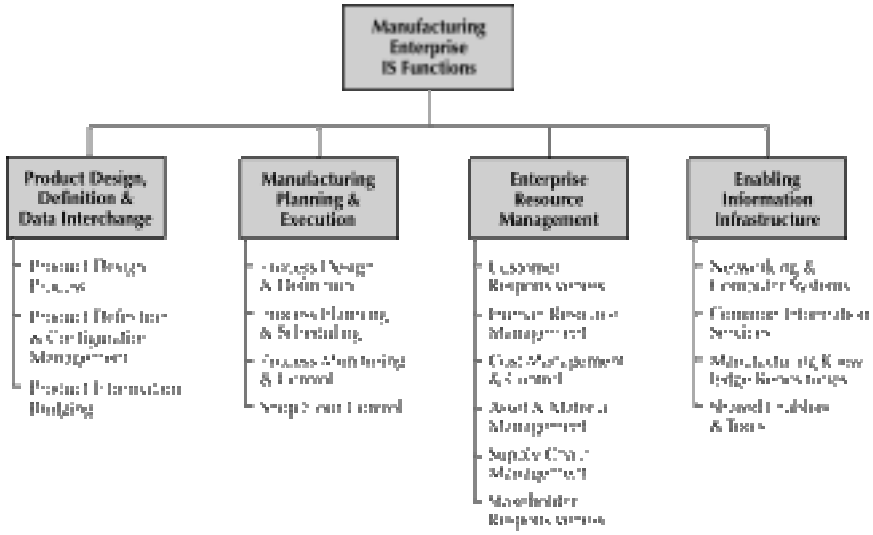
Some tidbits from the Roadmaps

- Information Systems
- Modeling and Simulation
- Technologies for Enterprise Integration

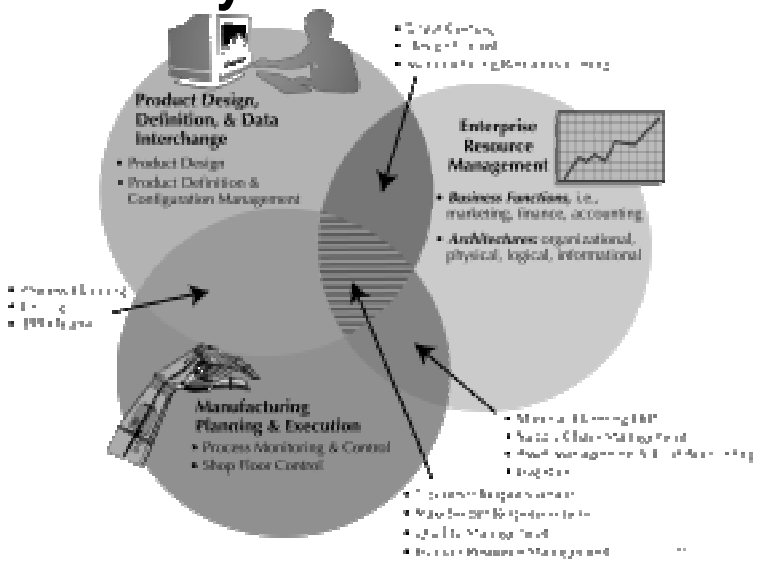
Current State - Information Systems Are Revolutionizing Manufacturing Enterprises

- High-speed networks link the manufacturing enterprise
- Customer empowered by information technology through electronic commerce
- Concept design and optimization becoming systematized and integrated by linking modeling and simulation systems through networks
- Information systems are linking knowledge bases, on-line sensing systems, and on-line modeling and processing to achieve 100% correct product - first time and every time
- Product definition - total computer-sensible representation of the product - is a reality
- ERP and PDM - tremendous impact!

Information Systems Functional Model



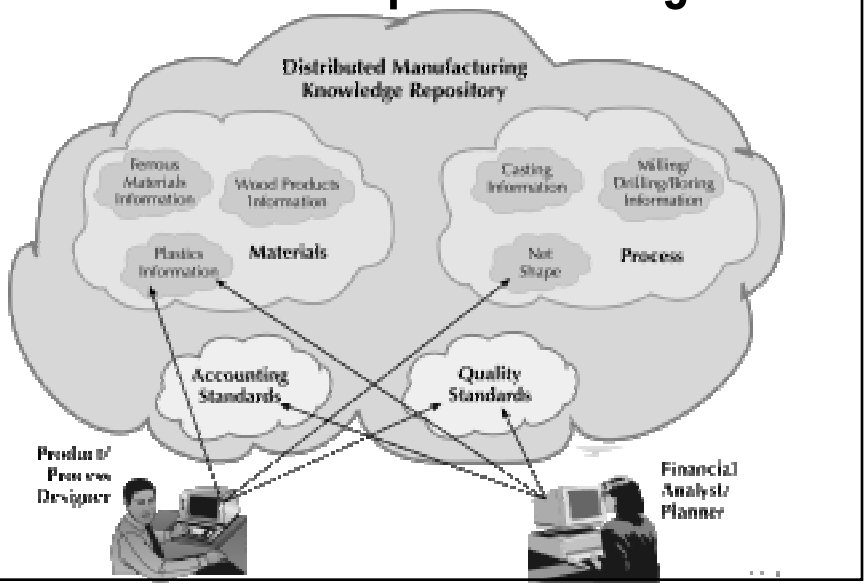
The Interrelationships of the Elements of Information Systems for Manufacturing



Product Design, Definition, & Data Interchange

FROM		TO
People-dependent design processes - widely variant	⇒	Product (and process) design and analysis - totally automated
Limited exchange of geometry data; use of national standards such as PDES/STEP	⇒	Product data seamlessly exchanged - globally and for all product life-cycle stages
Design as a stand-alone function with emerging collaboration and little on-line analysis	⇒	All enterprise elements participate in design, supported by a rich toolset for analysis
Functional and performance models in limited use for design	⇒	Functional and performance models integrated for control of every step of product creation and lifecycle

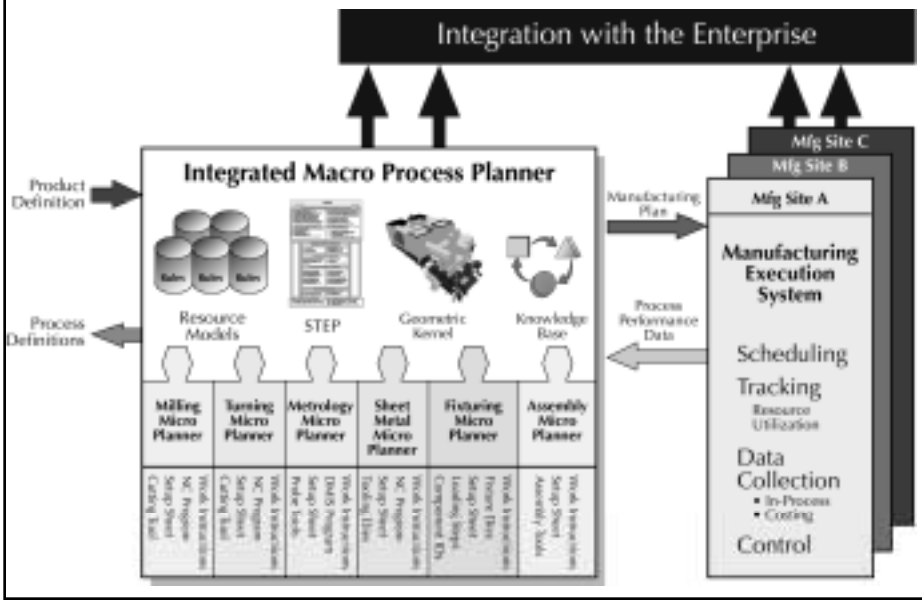
Access to All of the Needed Information - a Necessity for Product/process Design



Manufacturing Planning & Execution

FROM		TO
Largely manual process design	⇒	Knowledge-based design advisors
Integrated Product & Process Development largely means functional collaboration	⇒	IPPD matured to Integrated Product Realization - from concept though the lifecycle
Shop floor control (transaction) as a separate function - large systems	⇒	Integrated schedulers and shop floor control systems for reactive and adaptive control
Manufacturing information generated by disparate systems and manual operations	⇒	Generative planning systems create all manufacturing information as part of an integrated ERM environment

An Integrated Manufacturing Planning Framework



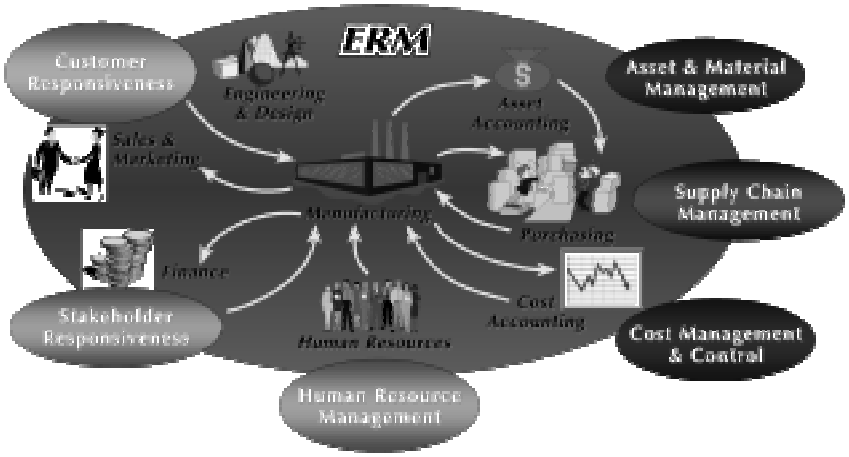
Enterprise Resource Management

FROM	TO
Quality Function Deployment to establish customer requirements; requirements management systems emerging	Requirements-driven design, direct ordering, and customer driven tradeoff for optimization
Some skills databases, computer-based training emerging; productivity enhancement through teaming	Clear visibility of skill needs, trends, availability; knowledge supply chain in operation; integrated tools for teaming
Disparate accounting methods, long delay between data collection and availability	Continuous, real-time visibility of financial information; financial management a standard parameter in design

Enterprise Resource Management (cont.)

FROM	TO
Barriers in supply chain - legal, disparate systems, specific supplier qualification systems	Extended enterprise interoperability; seamless participation in multiple supply chains; validated vendor and enterprise core competencies
Large ERP systems with major overhead; increasing awareness of need for flexibility and best-in-class tools; early integration with operations systems	Modular, plug-and-play ERM systems with best-in-class tools integrated with operations systems across the enterprise

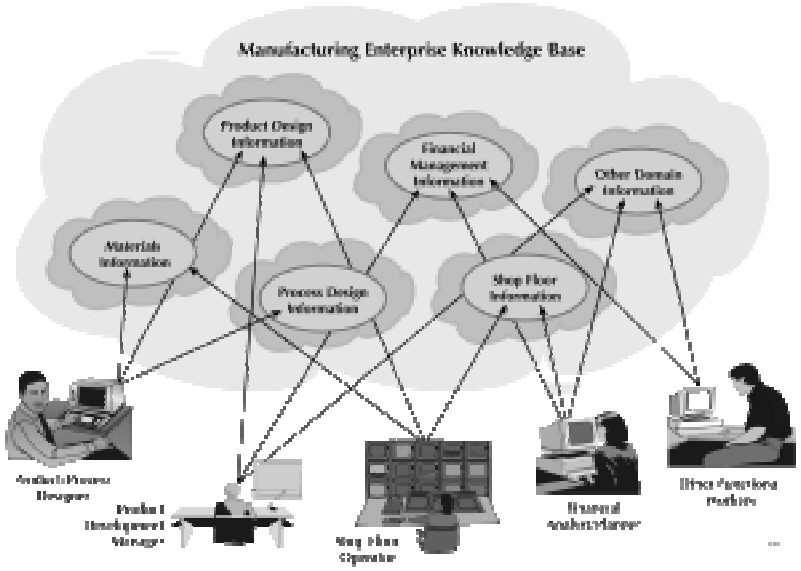
A Vision of Enterprise Resource Management



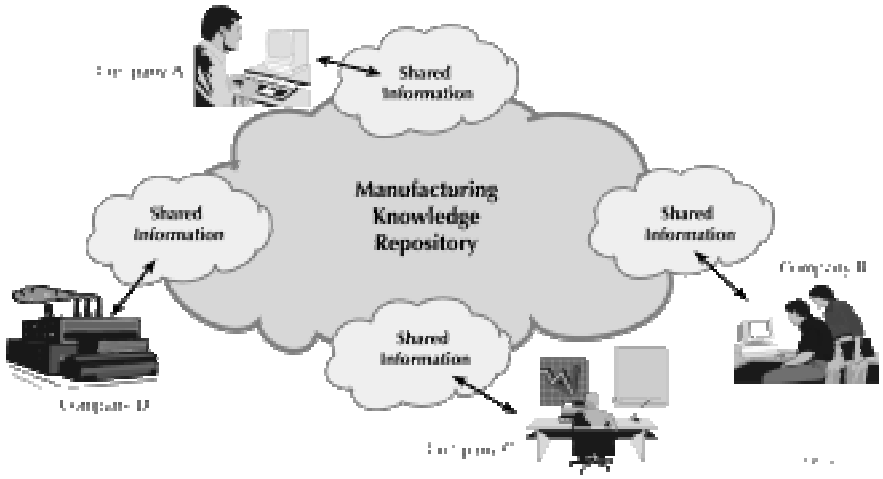
Enabling Information Infrastructure

FROM		TO
Tremendous growth in network capability, reliability, and capacity	⇨	Real-time access to all needed information; zero-loss transmission; only "net changes" transmitted
Labor-intensive data collection and management; large, custom information systems used to integrate data	⇨	Modular, reconfigurable, self-organizing information systems
Knowledge management "being discovered" as a major need; conversion of data to knowledge is external to data structure	⇨	Manufacturing knowledge available on demand through shared repositories; knowledge systems pervasive in design and manufacturing; self-learning and self-healing keep systems current

Manufacturing Enterprise Knowledge Base



Manufacturing Knowledge Sharing



Gold Nuggets - Information Systems for Manufacturing Enterprises

- Information-Driven Seamless Enterprises
- Shared Knowledge Repositories
- Customer/Requirements-Driven Manufacturing
- Mature Integrated Product/Process Design
- Totally Connected Extended Enterprise
- Plug-&-Play, Interoperable System Components
- Design & Operation Advisors
- Self-Correcting, Adaptive Operational Systems
- Self-Learning Systems
- Integration of Multiple Design Domains

In Summary

By implementing this migration strategy, manufacturing systems will:

- Have real-time access to all of the information they need - instantly useable
- Execute optimized processes with all important factors continuously balanced and tuned
- Anticipate and solve problems before they impact performance
- Exploit opportunities to their fullest potential

So What?

This "total connectedness" will enable enterprises to:

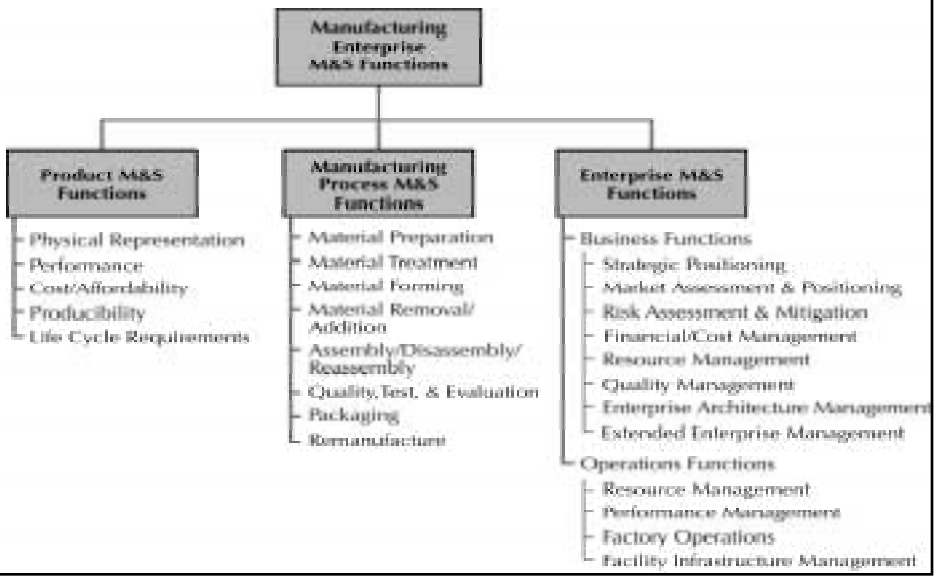
- **Manage and control engineering, manufacturing, distribution,**
  and support operations - anywhere in the world
- **Optimize product designs and manufacturing processes for**
  100% quality - first time and every time
- **Dramatically shorten the design-to-manufacturing cycle**
- **Quickly and efficiently respond to challenges and opportunities**
- **Create, integrate, and manage collaborative teams (enterprises)**
  to respond to the marketplace

TC 50

M&S - the way products and processes are developed and enterprises are operated!

- Model/simulation-based design -- eliminate costly design/test/fix cycles *(develop digitally - validate physically)*
- Process modeling to assure optimized performance and parameters (*the simulation becomes the controller!*)
- Multiscale-multiphysics capabilities couple formulation & microstructure to large scale assets.
- "Virtual Cockpits" -- "operate" product models, simulate launch scenarios, and manage operations to trade off requirements and features (*optimization via cognitive models)*
- Decision effectiveness -- enterprise models that access business and operational information and respond in real time *(design the enterprise and operate it adaptively)*

Modeling and Simulation - Functional Model



Product Modeling & Simulation Functions

FROM		TO
Solid models of nominal shapes; limited ability to model complex structures (e.g.. disordered); many attributes captured only as notes	⇨	Fully integrated, infinitely scaleable building blocks for perfect product models -couple conceptual and engineering design via knowledge management
Performance modeling limited to specialized domains	⇨	Multi-variable performance advisors plug and play in the design work process
Bottom-up cost modeling from the component level; little linkage to real-time data or sharing of cost models	⇨	Performance-based life-cycle cost modeling with real-time feedback and automatic updates

Product Modeling & Simulation Functions (Cont.)

FROM	TO
Lengthy simulation times; limits on number of alternatives; well known relationships	All producibility factors modeled in an integrated design system (business, product, and process models)
Limited integration of life-cycle, product support, and environmental factors	All life-cycle considerations included in product model; complete optimization for total life-cycle performance
Analysis supports design	Analysis leads design by providing analysis of conceptual designs and design intents through advances in parametric modeling, variational analysis, and probabilistic design

Process Modeling & Simulation Functions

FROM	TO
Excellent analytical M&S capability for continuous process industries	Best processes assured through automated process model – generated from design models and enterprise data (automagically)
Good base of material models for traditional materials; emerging base for non-traditional materials (composites)	Validated, science-based models for all materials and for new material creation
Disconnects in transformations	Micro to macro continuum modeling - atomistic, molecular, mesoscale, continuum scale

Process Modeling & Simulation Functions (Cont.)

FROM		TO
First principles for test and evaluation are well understood, but modeling implementations are limited	⇒	Knowledge systems operate transparently within accurate models to design processes to meet product requirements
Controller simulations that provide evaluations of the performance of particular controller designs	⇒	Controller simulations that evolve to become the controller for processes and enterprise operations

Enterprise Modeling & Simulation Functions

FROM		TO
Trends, tracking, and static enterprise models. Templates, spreadsheets in common use	⇒	Models enable deep understanding and accurate predictions for strategic positioning, risk tolerance
Market assessment modeling mostly based on personal wisdom and limited data	⇒	Real-time awareness and accurate prediction of market direction, enabling desired response
Static financial simulations and tradeoffs are common; ERP Systems driving the need for robust, integrated enterprise cost models	⇒	Accurate, fast modeling of all cost factors involved in contemplated decisions - across the enterprise

Enterprise Modeling & Simulation Functions (Cont.)

FROM		TO
ERP systems are demanding better resource models; the models and tools are expensive and complex; available data often insufficient, inaccurate	⇨	Total visibility, quick response and precise control of all enterprise resources through real-time models
Enterprise models are custom-built and address limited domains; some architectures exist, but no standards	⇨	Flexible, hierarchical, inter-connected enterprise models give managers immediate access to all desired information; architecture provides framework plug & play of all enterprise systems

Enterprise Modeling & Simulation Functions (Cont.)

FROM		TO
Current M&S tools are chiefly Single-function and don't support supply chains; some distributed ERP pilots under way	⇨	Extended enterprise management systems, based on self-integrating operational models, enable instant teaming and seamless interoperation of complex supply chains
Process models increasingly used for operations design - mostly off-line and static; continuous process industries lead the cutting edge of model based control	⇨	Science-based models continuously enhanced with live performance data provide accurate, real-time adaptive control of all enterprise systems and processes

Gold Nuggets - Modeling and Simulation for Manufacturing

- Micro to Macro Continuum Modeling
- Science-Based Models Integrated with Living Knowledge/Experience Bases
- Intelligent Design & Analysis Advisors
- M&S as Real-Time Enterprise Controller
- Smart, Self-Learning Models
- Open, Shared Repositories & Validation Centers
- Integrated, Robust Product & Process Models for All Domains/Applications
- Seamless Interoperability
- Real-Time, Interactive, Performance Models

In Summary

- Modeling and Simulation will be the way products and processes are designed and processes are executed.
  - A single product and process model as the interface to all manufacturing information
  - Smart, self-correcting, self-learning systems adapt in real time to changes and opportunities
  - Process models as "controllers" for intelligent processes - connected to the shop floor
- Accurate, integrated business models will streamline business operations and assure responsiveness across the supply chain
- Validated models in plug-and-play framework will self-assemble on a M&S backbone for development and operation of manufacturing systems

The Business Case for Enterprise Integration

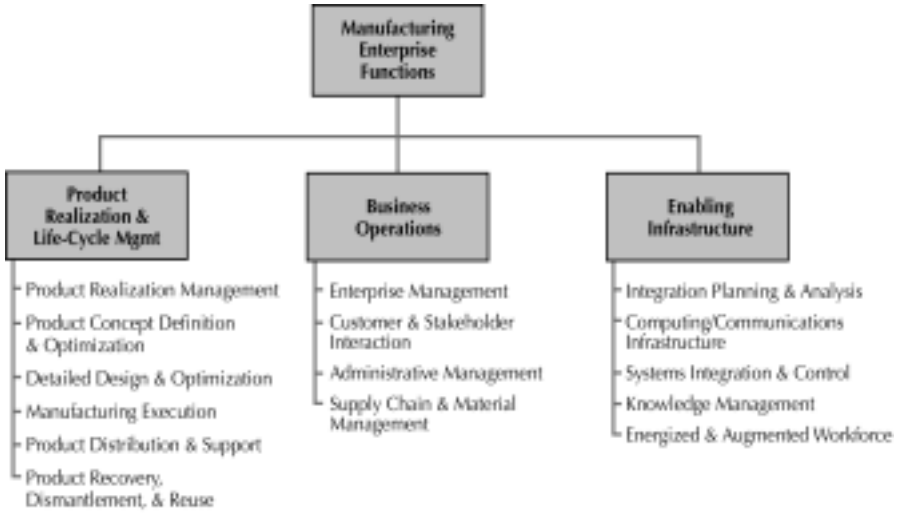
- Incompatible communications are costing too much money & time, and single-source solutions are unacceptable
- Design-to-manufacturing time is too long and product & process development costs are too high
- Multiple non-integrated systems don't work, and Enterprise Resource Planning is to costly and inflexible
- As companies move from manufacturing organizations to supply chain managers, costs must be cut. In some studies, 60% of product cost is in the supply chain, and 50% of that can be saved
- Instant and improved visibility of status and changes, and the ability to predict and react are success discriminators for the next century

Why Integrate? Some Results:

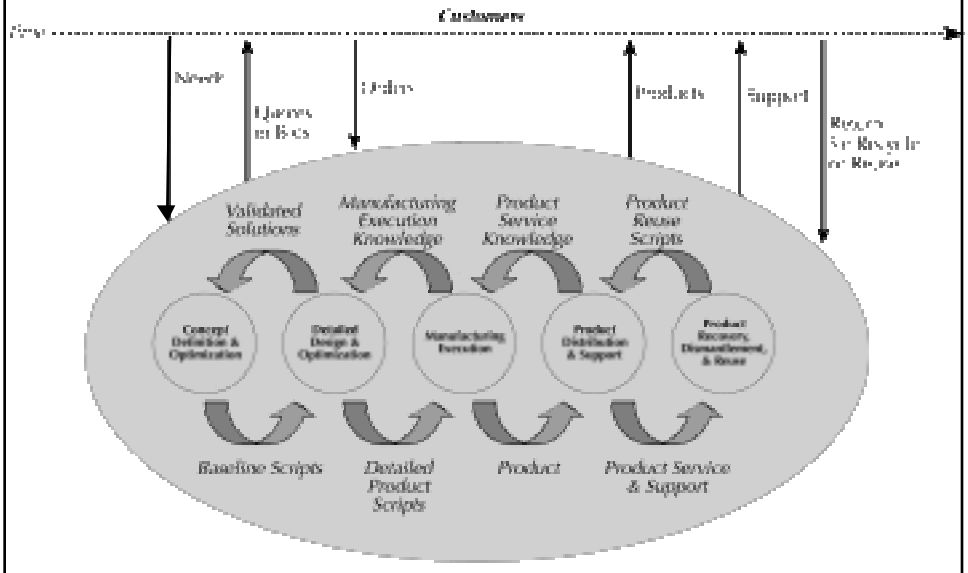
- Allen-Bradley:
  - 80% reduction in order-to-shipment time: 250% increase in shipments
- Deere & Company
  - 60% reduction in overhead: 30-50% reduction in time to market
- DEC
  - 50% reduction in new product development time
- HP
  - 50% reduction in direct labor cost: 73% reduction in handling cost
- Northern Telecom
  - 75% reduction in order-to-delivery time
- TI
  - 22.5-fold increase in production volume
- Westinghouse
  - 85% reduction in manufacturing cycle time

Source: David Dilts, CAM-I Competitively Integrated Enterprise, Vol. I

Technologies for Enterprise Integration - Functional Model



Integrated Product Realization



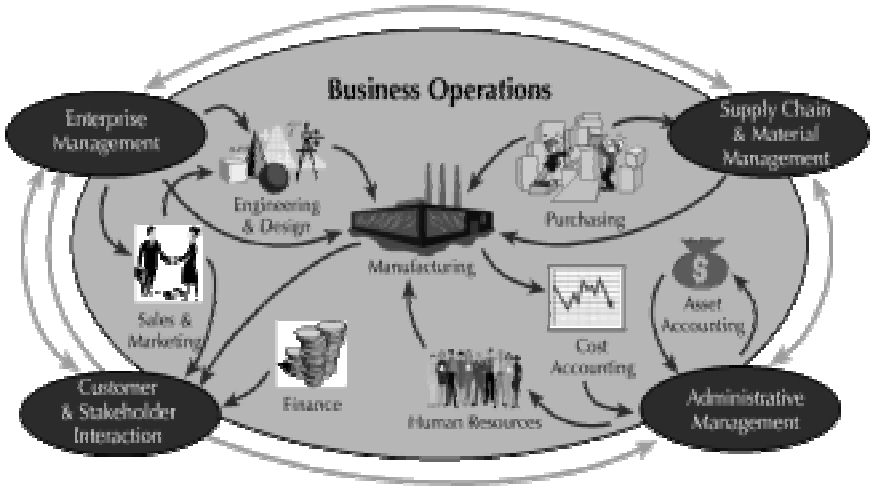
Integrated Product Realization and Life Cycle Management

FROM	TO
Concurrent Engineering, Integrated Product and Process Development and Integrated Product (IPPD) Teams	Full, seamless, integration of all functions, applications, processes and operations across all phases of the product lifecycle. *"Instant Engineering"*
Concept development often based on predictive and iterative interaction with the potential market/customer; Quality function deployment and requirements management tools	Requirements driven virtual prototypes with customer specified options evaluated in real-time and automated trade-offs for optimization based on agreed criteria

Integrated Product Realization and Life Cycle Management

FROM	TO
Detailed designs based on static historical data with wide use of physical prototypes and iteration	Mature institutionalized IPPD with automated "cockpits" leading to best decisions and knowledge- based generative systems creating the best manufacturing information
Great variability in design strategies	Knowledge-based design conventions as part of an integrated design environment

Business Operations Management



Business Operations

FROM		TO
Evolution from ERP to ERM, but integrated solutions are expensive and inflexible; limited integration of business and operations functions	⇒	Enterprise management as the integration of all functions of the enterprise - knowledge based and supported by real-time enterprise models
ERP/ERM systems that internally integrate	⇒	Multi-enterprise ERM systems that rapidly interconnect other ERM systems to create a virtually integrated enterprise - quickly and efficiently
ERP with increasing flexibility and "best-in-kind" selection	⇒	Fully modular ERM with plug-and-play best in kind tools and self integration with other systems

Business Operations

FROM		TO
Increasing awareness of customer needs and response to those needs	⇨	Clear visibility of stakeholder needs and trends and on-line decision support in assuring the best response
Internet based electronic commerce emerging as the standard for business-to-business functions	⇨	Mature electronic commerce that support seamless operation of truly global enterprises
Growing from supply chain emphasis - to supply chain management – to enterprise supply chain management; current systems lack flexibility for agile supply chain management	⇨	Modular, inexpensive, self-integrating systems that enable different partners to integrate business and production operations instantly without regard for location or functional differences

Infrastructure Enablers

FROM		TO
Extensive reliance on systems vendors for “engineered integration”; integration planning is largely manual	⇨	Enterprise architectures based on standard reference models and configured based on requirements
Internet emerging as a global backbone but bandwidth and speed are insufficient and legacy system integration is a huge issue	⇨	Ubiquitous global networks with virtually infinite capacity and speed; transparent connectivity throughout the extended enterprise
Increasing compatibility of systems and applications across platforms, but still lots of translation, user interfaces, and data conversion	⇨	Total seamless interoperability through global standards and adaptive, self-integrating systems

Infrastructure Enablers

FROM		TO
Enterprise knowledge housed in individual capability and captured on paper; Advisors and expert systems are mostly "ad hoc" designs	⇨	Knowledge management as a major function of the enterprise; knowledge applied in employee training, design of products and processes, decision making . . . All functions of the enterprise
Skills management as an manual process	⇨	Human skills augmented by enterprise knowledge to maximize potential and rewards for the enterprise and the individual

Gold Nuggets - Technologies for Enterprise Integration

- Coupling of Business & Production in Enterprises
- Seamlessly Integrated & Interoperable Supply Chains
- Manufacturing as an Integrated System (Integrated Product Realization)
- Totally Integrated Life-Cycle Management
- Self-Integrating Systems & Processes
- Web-Based Manufacturing
- Seamless Knowledge Management Across Extended Enterprises
- Mature Electronic Commerce
- Human Enablement via Technology
- Customer-Responsive Concept Development

In Summary

- Integrated Product Realization - from concept to life-cycle management is a theme that will revolutionize the design to manufacturing cycle.
- Supply Chain Management - The decade of the 1990's was a time of awakening to supply chain issues. The next decade - the supply chain may be the biggest discriminator. Example: Pratt Whitney transition from 6 million square feet of manufacturing space to 3 million square feet and a supply chain.
- Enterprise resource management will be a marriage of robust real-time enterprise modeling, and modular, best-in-class ERM tools for business and operations
- Interoperability - soon, like quality, a given

You Can Have The Full Story

http://www.IMTI21.org

The IMTI Vision for Information Systems

REAL time information systems that provide all of the right information, to the right place, at the right time, and in the right format

The IMTI Vision for Modeling and Simulation

- **Digitally developed products and processes**
- **Processes controlled by real-time, integrated process models**
- **An enterprise wide model driven business and operations environment**

Technologies for Enterprise Integration

Plug and play enterprises, totally connected in a plug-and-play environment, integrating business and operations functions for instant response across the supply chain